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(19)

(54) METHOD OF INHIBITING FUNGAL GROWTH ON REFRIGERATED FRESH FRUITS AND VEGETABLES

(71) We, TRANSFRESH CORPORATION, a corporation of the State of Delaware, United States of America, having a place of business at 607 Brunken Avenue, Salinas, California 93901, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to inhibiting the growth of fungi on fresh fruits and vegetables in refrigerated containers, whether fixed or movable, using a preservative modified gaseous environment.

This invention relates to an improvement in or modification of the invention of our co-pending Application No. 28297/76 (Serial No. 1551432), which is concerned with preserving gruits and vegetables by maintaining them under a refrigerated temperature in the range 29—60°F and in preservative modified atmospheres including carbon monoxide in fungistatic amounts of 5% to 25% by volume, molecular oxygen in an amount of 1.8% to 30% by volume, carbon dioxide in an amount of 1 to 20% by volume, and the remainder substantially all molecular nitrogen.

In accordance with one aspect of the present invention there is provided a process for inhibiting the growth of fungi on fresh fruits or vegetables comprising maintaining the said fruits or vegetables at a temperature in the range of 29° to 60°F in a modified gaseous atmosphere including in amounts by volume, carbon dioxide from zero to 20%, molecular oxygen from 1% to 20%, carbon monoxide from 3% to 25%, and the remainder substantially all molecular nitrogen, provided that the said atmosphere does not conform to the following composition by volume: carbon dioxide 1% to 20%, molecular oxygen 1.8% to 30%, carbon monoxide 5% to 25%, balance substantially all molecular nitrogen.

Refrigeration refers to temperatures in the range of 29° to 60°F., depending on the requirements of the particular fruit or vegetable. Examples of fresh fruits and vegetables are bell peppers, cauliflower, mushrooms, grapes, blueberries, referred to in Application No. 28297/76 (Serial No. 1551432).

In accordance with a further aspect of the present invention there is provided a process for inhibiting the growth of fungi on bell peppers which comprises maintaining the peppers at a temperature in the range of 29° to 60°F in a modified gaseous atmosphere including, by volume, carbon dioxide from 1% to 10%, oxygen from 5% to 20%, carbon monoxide from 3% to 25%, balance substantially all nitrogen, provided that the said atmosphere does not conform to the following composition by volume: carbon dioxide 2% to 20%, molecular oxygen 3% to 7%, carbon monoxide about 10%, remainder substantially all molecular nitrogen.

More especially in accordance with the present invention, tomatoes, squash, pineapples, peaches, papayas, nectarines, mangoes, melons, eggplant, cabbage, avocados, lettuce, apples, pears, apricots, cherries, potatoes, sweet potatoes, and anions, are maintained at a temperatures in the range 29° to 60°F in a modified gaseous atmosphere including, by volume, carbon dioxide from zero to 20%, molecular oxygen from 1% to 20%, carbon monoxide from 3% to 25%, balance substantially all nitrogen.

The amounts of oxygen and carbon dioxide used vary with the kind and variety of fruit or vegetable subjected to the preservative modified atmospheres of this invention.

The amount of carbon monoxide used is at least the amount sufficient to inhibit the growth of fungi on the particular fruit or vegetable. That amount will vary depending upon the nature of the fruit or vegetable, the variety of that fruit or vegetable, the length of time between harvesting of the fruit or vegetable, and the application of atmospheres of this invention and the kind of fungi involved. It preferably constitutes from 5% to 15% by volume.

The following table shows broad and more preferred ranges of carbon dioxide, oxygen and carbon monoxide for use with the kind of fruit or vegetable shown.

FRUIT or Vegetable	Broad Ranges Percent by Volume CO_2	O_2	CO	N_2	More Preferred Ranges Percent by Volume CO_2	O_2	CO	N_2
Bell Pepper	1–10	5–20	3–25	BALANCE	2–7	5–10	5–15	BALANCE
Cauliflower	1–10	3–20	3–25	BALANCE	3–6	5–10	5–15	BALANCE
Mushroom	3–20	3–20	3–25	BALANCE	5–10	10–15	10–20	BALANCE
Grape	0–15	2–15	3–25	BALANCE	0–10	5–10	10–20	BALANCE
Blueberry	1–15	2–10	3–25	BALANCE	5–10	3–5	5–15	BALANCE
Tomato	0–7	3–10	3–25	BALANCE	0–5	4–8	5–15	BALANCE
Squash	3–15	2–10	3–25	BALANCE	5–10	3–8	5–15	BALANCE
Pineapple	1–15	2–15	3–25	BALANCE	5–10	5–10	5–15	BALANCE
Peach	1–10	2–10	3–25	BALANCE	3–6	3–6	5–15	BALANCE
Papaya	2–10	2–10	3–25	BALANCE	4–8	3–8	5–15	BALANCE
Nectarine	1–10	2–10	3–25	BALANCE	3–6	3–6	5–15	BALANCE
Mango	2–10	2–10	3–25	BALANCE	4–8	4–8	5–15	BALANCE
Melon	2–10	3–15	3–25	BALANCE	10–15	5–10	5–15	BALANCE
Eggplant	0–8	2–10	3–25	BALANCE	0–3	4–8	5–15	BALANCE
Green Beans	2–10	2–10	3–25	BALANCE	3–5	3–6	5–15	BALANCE
Apples	1–10	1–10	3–25	BALANCE	2–8	1–4	5–15	BALANCE
Pears	0–8	2–8	3–25	BALANCE	1–5	1–3	5–15	BALANCE
Apricots	1–8	2–8	3–25	BALANCE	2–5	2–5	5–15	BALANCE
Cherries	3–20	2–15	3–25	BALANCE	5–15	3–10	5–15	BALANCE
Cabbage	1–10	2–10	3–25	BALANCE	3–6	3–6	5–15	BALANCE
Avocado	3–15	2–10	3–25	BALANCE	5–10	3–6	5–15	BALANCE
Lettuce	0–5	2–15	3–25	BALANCE	0–3	5–10	5–15	BALANCE
Potato	5–20	3–10	3–25	BALANCE	5–10	4–8	5–15	BALANCE
Onion	4–15	1–7	3–25	BALANCE	5–10	2–5	5–15	BALANCE
Sweet Potato	3–5	5–7	3–25	BALANCE	2–7	4–8	5–15	BALANCE

Not all concentrations of these gases are effective or equally effective on each and every kind and variety of fruit and vegetable. At certain temperatures and with certain mixtures of gases, physiological or pathological damage to certain fruits and vegetables may occur, even though fungi growth is inhibited. Such conditions may readily be determined and then avoided.

The following are examples of the present improvement or modification. In the examples, all percentages are percentages by volume unless the contrary is expressly stated.

Example 1: *Avocado Storage.*

Two groups of 24 avocados each were placed in separate containers. The atmosphere in the first container was modified to contain initially a preservative atmosphere including about 10% carbon dioxide, about 8% carbon monoxide, about 3% oxygen, the balance all substantially molecular nitrogen. The atmosphere in the second container was air. The temperature inside each container was modified to and maintained at 55°F. for 16 days. During this time, the atmosphere in the first container was monitored, and adjustments were made to maintain the gas concentration close to the starting concentration.

At the end of the storage period, avocados held in the second container were soft, ripe and had slight mold growth on their stem buttons. Avocados held in the first container were hard, green and free of mold growth. After these observations were made, the avocados from the first container were held in air at about 70°—75°F. for one day, and then at 45°F. in air for another day. Avocados that had been held in the first container were slightly soft. About half were still green; the other half were purple-brown in color, indicative of partial ripening.

Neither the avocados held in air nor the avocados held in preservative atmosphere developed any chilling symptoms or decay. This example shows that carbon monoxide is an effective fungistat on avocados when used in combination with carbon dioxide and oxygen.

Example 2: *Cabbage Storage.*

Two groups of cabbage heads, each including twelve heads, were placed in separate containers. The atmosphere in the first container was modified to contain initially about 5% carbon dioxide, about 5% carbon monoxide, and about 5% oxygen. The atmosphere in the second container was air throughout the test. The temperature within each container was modified to and maintained at 42°F. for three weeks. During this time, the atmosphere in the first container was monitored, and adjustments were made to maintain the gas concentrations close to the starting concentrations.

At the end of this period, the cabbages held in air had turned substantially completely yellow, and mold growth was visible on the wrapper leaves. Cabbages held in the preservative atmosphere were in good condition. The leaves had not yellowed and little mold growth was visible.

The improvement that carbon monoxide produced was particularly striking because the quality of the cabbage at the outset of the test was poor; cabbages then had severe leaf spotting on both wrapper and cap leaves.

Example 3: *Eggplant Storage.*

Five groups of 18 eggplants each were placed in separate containers. In four of the containers, the atmosphere was modified to contain initially the following:

Container 1: About 1%—3% carbon dioxide, about 5% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 2: About 7% carbon dioxide, about 5% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 3: About 1%—3% carbon dioxide, about 5% oxygen, and the balance substantially all molecular nitrogen.

Container 4: About 7% carbon dioxide, about 5% oxygen, and the balance substantially all molecular nitrogen.

The atmosphere in container 5 was air throughout the test. The temperature in each of the containers was adjusted to and maintained at 45°F. for two weeks. During this time, the atmospheres in the first four containers were monitored and adjustments were made to maintain the gas concentrations close to the starting concentrations.

After the two week period, the eggplant held in air had poor color, severly molded calyxes, and some pitted surfaces, indicating that Alternaria rot had begun to develop.

By contrast, eggplant held in containers 1 and 2 retained good green color in the calyxes, had little or no decay, and retained a fresh appearance. Eggplant held in container 1 appeared slightly better than the eggplant held in container 2.

Eggplant held in containers 3 and 4 were in poor condition. Calyxes on these eggplant had as much mold as eggplant held in air, and some scalding of eggplant surfaces had also occurred.

Example 4: *Lettuce Storage.*

Three groups of iceberg lettuce, each containing 24 heads, were placed in separate containers. The atmosphere in the first container was modified to contain initially about 10% oxygen, about 9% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the second was modified to contain initially about 10% oxy-

gen, about 15% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the third contained air throughout the test. The temperature in each container was maintained at about 340°F. for 19 days. During the test, the atmosphere in containers 1 and 2 was monitored, and adjustments were made to maintain the gas concentrations close to the starting concentrations.

At the end of the 19-day period, half of the heads were moved and inspected immediately, and the other half were held at about 70°—75°F. in air for two days and then inspected. The results were as follows:

After 19 days, three of the 12 heads held in air exhibited Botrytis rot; none of the 24 lettuce heads held in the carbon monoxide-containing atmospheres showed any. Forty-eight hours later, nine of the 12 lettuce heads held in air exhibited Botrytis rot; none of the remaining lettuce heads held in the carbon monoxide-containing atmospheres exhibited any such rot. These results show that carbon monoxide effectively controls fungi growth that otherwise causes severe damage to lettuce.

Example 5: *Lettuce Storage.*

Two groups of iceberg lettuce, each containing 60 heads, were placed in separate containers. The atmosphere in the first container was modified to produce an atmopsphere initially containing about 8% oxygen, about 20% carbon monoxide, and the balance substantially all molecular nitrogen. The second container held air throughout the test. The temperature in each container was lowered to and maintained at about 33°—34°F. for two weeks. During that time, the atmosphere in the first container varied from about 20% carbon monoxide to about 7%, and the oxygen, from about 8% to about 10%.

At the end of the two week period, none of the lettuce held in the first container exhibited Botrytis, but two of the lettuce heads held in air did. Moreover, only 12 of the heads held in the first container exhibited developing soft rot; 22 from the air control did. Severity of decay was considerably lower for lettuce heads treated with carbon monoxide than for lettuce heads held in air without carbon monoxide. Again, carbon monoxide appeared to inhibit substantially the growth of Botrytis fungi and bacterial soft rot on lettuce.

Example 6: *Honeydew Melon Storage.*

Five groups of five honeydew melons each were placed in separate containers. The atmosphere in four of the containers was modified; the atmosphere in the fifth was air throughout the test. The modified atmospheres were as follows:

Container 1: Zero to about 2% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, andw the balance substantially all molecular nitrogen.

Container 2: About 5% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 3: About 10% carbon dioxide, about 5% oxygen, about 10—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 4: About 15% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

The atmosphere in each container was maintained at about 50°F. for three weeks. During this time, the atmosphere in each of the first four containers was monitored, and adjustments were made to maintain the gas concentration close to the starting concentrations.

The containers were opened after the three week period, and the melons inspected. Those in the modified atmosphere treatment were free from rot and mold growth. Three of the five melons from the air control exhibited decay, mold growth or both.

After holding the melons from each of the containers at about 70°—75°F. in air for four days, four of the five melons held exhibited decay, but none of the melons held in modified atmosphere did. No rind blemishes developed in melons held in modified atmospheres, and the taste and aroma of all melons, including those heled in air, was normal.

Example 7: *Cantaloupe Storage.*

Six groups of 16 cantaloupes each were placed in separate containers. The atmospheres in five of the containers were modified to contain the following:

Container 1: Zero—about 2% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 2: About 5% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 3: About 10% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 4: About 15% carbon dioxide, about 5% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 5: About 0—5% carbon dioxide, about 21%—4% oxygen, about 10%—15% carbon monoxide, and the balance substantially all molecular nitrogen.

The sixth container held air throughout the test. The temperature in each container was lowered to and maintained at about 50°F. for three weeks. During the three weeks, the gas concentrations in containers 1 through 5

were monitored, and adjustments were made to maintain the gas concentrations close to the starting concentrations. However, in container 5, the oxygen concentration was permitted to decrease from 21% at the outset to 4% at the end of the three week period.

At the end of the three weeks, the containers were opened and the canteloupes examined. All melons exhibited some mold and decay, but the carbon monoxide-treated melons exhibited substantially less decay than cantaloupes held in air. Higher concentrations of carbon dioxide in combination with carbon monoxide enhanced inhibition of the fungi.

Example 8: *Nectarine Storage.*

Four groups of nectarines, each containing from 25 to 30 fruit, were placed in separate containers. The atmosphere in three of the containers were modified to contain initially the following concentrations of gases:

Container 1: About 12% carbon dioxide, about 3% oxygen, and the balance substantially all molecular nitrogen.

Container 2: About 12% carbon monoxide, about 10% oxygen, and the balance substantially all molecular nitrogen.

Container 3: About 7% carbon dioxide, about 7% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

The fourth container held air throughout the test. The temperature of each container was lowered to 32°F. initially, but rose to 50°F. for at least part of the test period. During the three week period, the gas concentrations in each of the first three containers were monitored and adjustments were made to maintain the concentrations at or near the starting concentration.

After three weeks, the containers were opened and the fruit inspected. Of the 28 fruit in container 1, 8 exhibited some brown rot and some off-flavor. Of the 25 fruit in container 2, none exhibited brown rot, but some were off-flavor. Of the 25 fruit in container 3, none exhibited brown rot, and flavor was acceptable. Of the 31 fruit held in air, 12 exhibited brown rot, and again flavor was acceptable.

Carbon monoxide inhibited development of brown rot fungi without any detrimental impact on flavor. Moreover, where carbon monoxide was present, carbon dioxide could be maintained at lower levels, insuring preservation of good flavor.

Example 9: *Papaya Storage.*

Two groups of papaya, one containing 14 fruit, the other, 16 fruit, were placed in separate containers. The atmosphere in the first container was modified to contain initially an atmosphere of about 10% carbon dioxide, about 3% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the second container was air throughout the test. The temperature in each container was modified to, and held at 55°F. for 10 days. During the 10 days, the atmosphere in the first container was monitored, and adjustments made to maintain gas concentrations at or near the initial concentrations.

At the end of 10 days, papayas held in air were riper than those held in the modified atmosphere. All fruit was held another four days at about 70°—75°F. in air to observe ripening and shelf life. At the end of four days, fruit held in modified atmosphere was still not nearly as ripe as the fruit held in air throughout.

None of the fruit developed any Anthracnose rot, but 4 of the 16 fruit held in air developed stem end rot. Only 1 of the fruit held in the modified atmosphere exhibited any stem end rot. Taste and aroma of all fruit was normal, indicating that carbon monoxide had no deleterious effect on flavor.

Example 10: *Peach Storage.*

Three groups of peaches of the Summerset variety, 100 fruit in each group, were placed in separate containers. The atmosphere in the first container was modified to contain initially about 3% carbon dioxide, about 4% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the second container was modified to contain about 5% carbon dioxide, about 5% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen. The third container held air throughout the test. The temperature in each container was reduced to and held at about 32°F. for five weeks. During this time, the gas concentrations in the first two containers were monitored, and adjustments were made to maintain the gas concentrations at or near the starting concentrations.

At the end of three weeks, the containers were opened, and 50 peaches were removed from each of the containers. Of the 50 peaches removed from the air container, 8 were decayed at mechanically damaged areas. Advancement of decay was moderate, and mycelial growth was abundant. Of the 50 peaches from container 2, 5 were decayed at mechanically damaged areas, but decay was much less advanced than with peaches held in air, and both mycelial growth and sporulation were inhibited. Of the 50 peaches held in container 1, 3 were decayed at mechanically damaged areas, but again, mycelial growth and sporulation were inhibited.

The rest of the peaches were held two more weeks in the containers under the same conditions. Of the 100 peaches from the two modified atmosphere containers, only 13 in all (6 from container 1 and 7 from container 2) were decayed at mechanically damaged areas.

Of the 50 peaches from the air control atmosphere, 22 were decayed in mechanically damaged areas. No mycelial growth or sporulation was evident on peaches held in modified atmospheres, but such growth and sporulation was profuse on peaches held in air. Moreover, peaches held in modified atmosphere containing the higher concentration of carbon dioxide had the best texture and taste of the three groups. Peaches held in the lower concentration of carbon dioxide and the peaches held in air were drier and much less tasty.

Example 11: *Bell Pepper Storage.*

Four groups of about 100 bell peppers each were placed in separate containers. In the first container, the atmosphere was modified to produce an atmosphere containing initially about 3% carbon dioxide, about 5% oxygen, about 25% carbon monoxide, and the balance substantially all molecular nitrogen. In the second container, the atmosphere was air throughout the test. The temperature in each container was reduced to and held at about 48° to about 50°F. for 23 days. During this time, the oxygen concentration varied from about 5% to about 10%, and the carbon monoxide concentration from about 25% to about 10% in the first container.

At the end of 23 days, the peppers were removed and observed. Peppers held in air had mold growth on all stems, and many exhibited severe rotting. Peppers held in the modified atmosphere were free of surface mold growth and rots.

In a separate test, a third group of peppers was placed in a third container, and the atmosphere therein modified to contain initially about 2% carbon dioxide, about 5% oxygen, about 15% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the fourth container, into which was placed the fourth group of bell peppers, was air throughout this second test. The temperature in the third and fourth containers was reduced to and maintained at about 48° to about 50°F. throughout a 14 day test period. Thereafter, the peppers were removed and observed, and results were comparable to those obtained with the peppers held in containers 1 and 2 for 23 days.

Example 12: *Zucchini Squash Storage.*

Six groups of Zucchini squash, each group containing about 110 to about 120 squash, were placed in separate containers. The atmospheres in 5 of the containers were modified to produce the following compositions:

Container 1: About 10% carbon dioxide, about 3% to about 5% oxygen, and the balance substantially all molecular nitrogen.

Container 2: About 10% carbon dioxide, about 3% to about 5% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 3: About 5% carbon dioxide, about 3% to about 5% oxygen, and the balance substantially all molecular nitrogen.

Container 4: About 5% carbon dioxide, about 3% to about 5% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 5: About 20% oxygen, about 10% carbon monoxide, and the balance substantially all molecular nitrogen.

The sixth container held air throughout the test. The temperature in each of the containers was reduced to and maintained at about 45°F. to 47°F. for two weeks. During this time, the atmospheres in containers 1 through 4 were monitored, and adjustments made to hold the concentrations at or near the starting concentrations. However, in the fifth container, the oxygen concentration was permitted to decrease naturally by respiration to about 3% at the end of the test period.

At the end of two weeks, the squash were removed and inspected. The squash held in air had surface mold growth on virtually the entire surface of all the squash. Ten squash held in air exhibited some decay. Squash held in container 1 had a small quantity of surface mold growth; 7 squash were slightly decayed. Squash held in container 2 had no decay and only traces of surface mold growth. Squash held in container 3 had the most surface mold growth and the highest number of decayed squash. The squash from container 4 were not decayed and exhibited only traces of surface mold growth. Squash held in container 5 had little decay but exhibited substantial mold growth, indicating that carbon dioxide also has a valuable role in preserving the life of this vegetable.

Example 13: *Tomato Storage.*

Three groups of 48 tomatoes each were placed in separate containers. The atmospheres in the first two contaniers were modified to produce the following:

Container 1: About 3% to about 5% oxygen, about 5% to about 10% carbon monoxide, and the balance substantially all molecular nitrogeen.

Container 2: About 3% to about 5% oxygen, and the balance substantially all molecular nitrogen.

The third container held air throughout the test. The temperature in each container was reduced to and held at about 50°F. for 23 days. During this time, the concentrations of gases in containers 1 and 2 were monitored, and adjustments made to maintain the concentrations at or near the starting concentrations.

At the end of 23 days, the tomatoes held in container 1 were free from rot. Tomatoes from containers 2 and 3 were severely rotted. This test proves that carbon monoxide effectively inhibits the growth of fungi on tomatoes.

Example 14: *Tomato Storage.*

Two groups of 72 tomatoes each were placed in separate containers. Half of each group had a color index of 2—3, the other half, 4—5. Atmosphere in container 1 was modified to contain initially about 5% oxygen, about 14% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in container 2 was air throughout the test. The temperature in each container was modified to and held at about 50°F. for two weeks. During that time, the gas concentrations in container 1 were monitored and adjustments made to maintain the concentrations at or near the starting concentrations.

At the end of two weeks, the tomatoes held in air had all advanced to a color index of 5. Those initially of index 4—5 were 40% decayed and surface mold growth was present on all stem scars. Those initially of color index 2—3 were about 20% decayed, and surface mold was present on about 50% of the stem scars.

Those tomatoes held in modified atmosphere that initially had the color index 4—5 advanced to color index 5 almost entirely, and were free of surface mold growth and decay. Those tomatoes held in modified atmosphere that had an initial color index of 2—3 were still substantially all at index 2—3, and were also free of surfac mold growth and decay.

Example 15: *Thompson Seedless Grape Storage.*

Four boxes of Thompson seedless grapes, each box containing about 20 pounds of grapes, were placed in separate containers. These grapes had been previously treated with sulfur dioxide in order to control decay. The atmospheres in the first three containers were modified to produce atmospheres initially having the following compoositions:

Container 1: About 10% carbon dioxide, about 5% to about 10% oxygen, about 10% to about 20% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 2: About 5% carbon dioxide, about 5% to about 10% oxygen, about 10% to about 20% carbon monoxide, and the balance substantially all molecular nitrogen.

Container 3: About 5% to about 10% oxygen, about 10% to about 20% carbon monoxide, and the balance substantially all molecular nitrogen.

The atmosphere in the fourth container was air throughout the test. The temperature in each of the containers was modified to, and held at about 33° to about 34°F. for 11 weeks. During this time, the gas concentrations in the first three containers were monitored, and adjustments made to maintain the concentrations of each of the gases at or near the initial concentrations. After four weeks, mold was evident in air control grapes. After seven weeks of storage, the air control grapes were a solid mass of nesting mold. All grapes held in modified atmospheres were free of rots and mycelial growth at the end of the 11-week period. These results were particularly striking because the ideal storage temperature for grapes is about 30° to about 31°F.

Example 16: *Grape Storage.*

Grapes of two varieties, namely Cabernet Sauvignon and Johannesberg Reisling, each variety including some grapes of grade one (rot free) and grade two (Alternaria field rot infected) were divided as follows for testing. Approximately one pound of grade one grapes from each variety was placed in a first container, and approximately one pound of grade two grapes of each variety was placed in a second container. Approximately the same quantities and combinations were placed in third and fourth containers to serve as controls.

The atmosphere in the first container was modifieed to produce a composition including about 5% to about 12% oxygen, about 15% to about 20% carbon monoxide, and the balance substantially all molecular nitrogen. The atmosphere in the second container was modified to produce a composition including about 2% to about 5% oxygen, about 20% to about 25% carbon monoxide, and the balance substantially all molecular nitrogen. The second container also included amounts of carbon dioxide that did not exceed about 1% at any time during the test. The atmosphere in the third and fourth containers was air throughout the test. The temperature in each of the containers was modified to and maintained at about 34° to about 35°F. for a 45-day period. During that time, the carbon monoxide and oxygen concentrations in the first two containers fluctuated between the values set forth above, and adjustments were made to maintain thesee values within these ranges throughout the test period.

At the end of 45 days, the grade 1 grapes from container 1 were free of mold growth. The Alternaria field rot infections on the grade 2 grapes from container 2 had not advanced, indicating that the rot infections were inhibited. By contrast, the grade 2 grapes from the air control container 4 were grossly rotted and mycelial growth was abundant. Mold growth on grade 1 grapes from container 3 was also objectionable though not as severe as that on grade 2 grapes from container 4.

WHAT WE CLAIM IS:—

1. A process for inhibiting the growth of fungi on fresh fruits or vegetables comprising maintaining the said fruits of vegetables at a temperature in the range of 29° to 60°F. in a modified gaseous atmosphere including in amounts by volume, carbon dioxide from

zero to 20%, molecular oxygen from 1% to 20%, carbon monoxide from 3% to 25%, and the remainder substantially all molecular nitrogen, provided that the said atmosphere does not conform to the following composition by volume: carbon dioxide 1% to 20%, molecular oxygen 1.8% to 30%, carbon monoxide 5% to 25%, balance substantially all molecular nitrogen.

2. A process for inhibiting the growth of fungi on bell peppers which comprises maintaining the peppers at a temperature in the range of 29° to 60°F. in a modified gaseous atmosphere including, by volume, carbon dioxide from 1% to 10%, oxygen from 5% to 20%, carbon monoxide from 3% to 25%, balance substantially all nitrogen, provided that the said atmosphere does not conform to the following composition by volume: carbon dioxide 2 to 20%, molecular oxygen 3 to 7%, carbon monoxide about 10%, remainder substantially all molecular nitrogen.

3. A process for inhibiting the growth of fungi on fresh fruits or vegetables selected from tomato, squash, pineapple, peach, papaya, nectarine, mango, melon, eggplant, green bean, apple, pear, apricot, cherry, cabbage, avocado, lettuce, potato, onion and sweet potato, which process comprises maintaining the said fruit or vegetable at a temperature in the range of 29° to 60°F. in a modified gaseous atmosphere including, by volume, carbon dioxide from zero to 20%, molecular oxygen from 1% to 20%, carbon monoxide from 3% to 25%, balance substantially all nitrogen.

4. The process of claim 3 wherein the vegetable is tomato, the carbon dioxide concentration is from zero to 7%, and the oxygen concentration is from 3% to 10%.

5. The process of claim 3 wherein the vegetable is squash, the carbon dioxide concentration is from 3% to 15%, and the oxygen concentration is from 2% to 10%.

6. The process of claim 3 wherein the fruit is pineapple, the carbon dioxide concentration is from 1% to 15%, and the oxygen concentration is from 2% to 15%.

7. The process of claim 3 wherein the fruit is peach, the carbon dioxide concentration is from 1% to 10%, and the oxygen concentration is from 2% to 10%.

8. The process of claim 3 wherein the fruit is papaya, the carbon dioxide concentration is from 2% to 10%, and the oxygen concentartion is from 2% to 10%.

9. The process of claim 3 wherein the fruit is nectarine, the carbon dioxide concentration is from 1% to 10%, and the oxygen concentration is from 2% to 10%.

10. The process of claim 3 wherein the fruit is mango, the carbon dioxide concentration is from 2% to 10%, and the oxygen concention is from 2% to 10%.

11. The process of claim 3 wherein the vegetable is melon, the carbon dioxide concentration is from 2% to 20%, and the oxygen concentration is from 3% to 15%.

12. The process of claim 3 wherein the vegetable is eggplant, the carbon dioxide concentration is from zero to 8%, and the oxygen concentration is from 2% to 10%.

13. The process of claim 3 wherein the vegetable is green bean, the carbon dioxide concentration is from 2% to 10%, and the oxygen concentration is from 2% to 10%.

14. The process of claim 3 wherein the fruit is apple, the carbon dioxide concentration is from 1% to 10%, and the oxygen concentration is from 1% to 10%.

15. The process of claim 3 wherein the fruit is pear, the carbon dioxide concentration is from zero to 8%, and the oxygen concentration is from 2% to 8%.

16. The process of claim 3 wherein the fruit is apricot, the carbon dioxide concentration is from 1% to 8%, and the oxygen concentration is from 2% to 8%.

17. The process of claim 3 wherein the fruit is cherry, the carbon dioxide concentration is from 3% to 20%, and the oxygen concentration is from 2% to 15%.

18. The process of claim 3 wherein the vegetable is cabbage, the carbon dioxide concentration is from 1% to 10%, and the oxygen concentration is from 2% to 10%.

19. The process of claim 3 wherein the fruit is avocado, the carbon dioxide concentration is from 3% to 15%, and the oxygen concentration is from 2% to 10%.

20. The process of claim 3 wherein the vegetable is lettuce, the carbon dioxide concentration is from zero to 5%, the oxygen concentration is from 2% to 15%.

21. The process of claim 3 wherein the vegetable is potato, the carbon dioxide concentration is from 5% to 20%, the oxygen concentration is from 3% to 10%.

22. The process of claim 3 wherein the vegetable is onion, the carbon dioxide concentration is from 4% to 15%, and the oxygen concentration is from 1% to 7%.

23. The process of claim 3 wherein the vegetable is sweet potato, the carbon dioxide conceentration is from 3% to 5%, and the oxygen concentration is from 5% to 7%.

24. Fruit or vegetables preserved by a process according to any preceding claim.

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